

Determination Of Relative Molecule Mass Volatile Compounds

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ABSTRACT

Volatile compounds easily evaporate at increased temperatures, leading to a decline in the quality of aroma and taste. These organic compounds typically have molecular weights between 50 and 200 Daltons, allowing them to evaporate and diffuse in gas and biological phases. The molecular weight of volatile compounds can be determined by measuring the density of their vaporized gas. Dalton's atomic theory (1807) states that matter consists of indivisible atoms with consistent properties within each element but differing between elements. The relative molecular mass is the ratio of the average molecular mass to the mass of a single carbon-12 atom. Ideal gases consist of particles moving randomly without interaction forces, and collisions are perfectly elastic. In 1802, Charles and Gay-Lussac formulated the ideal gas law, $pV=RT$, describing the relationship between pressure, volume, and temperature. This law helps determine the relative molecular mass of volatile compounds by vapor density measurement. In this study, chloroform (CHCl_3) was used as the volatile compound, its vapor density measured at 3.692 g/L, and its relative molecular mass calculated as 111.282 g/mol.

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1. Introduction

Volatile compounds evaporate easily and become gases when the temperature increases, generally to 100°C. If these compounds evaporate, their quality will decline. The molecular weight of volatile compounds can be measured by measuring the density of the evaporated gas. This is necessary to anticipate the amount of volatile compounds that will evaporate in each process, ensuring that the aroma and taste of the components are maintained [1].

Molecules are combinations of elements that share certain properties. Similar elements combine to form elemental molecules, while different elements form compound molecules. The molecular mass of an element or compound is expressed as relative molecular mass (Mr). Relative molecular mass is the sum of the relative atomic mass values (Ar) of the atoms that make up the molecule [2].



Volatile compounds evaporate easily. Volatile compounds have a lower M_r than non-volatile compounds. This is because volatile compounds have weaker intermolecular attractions than non-volatile compounds.

Molecular formulas are multiples of whole numbers and empirical formulas. They state the actual number of atoms that combine with chemical bonds to form a molecule. The molecular formula can be determined if the molecular mass from the empirical formula is known.

The number of moles of gas is usually expressed as n , which is also equal to the mass of the gas, m , divided by the molar mass, M (which has units of g/mol). So $n=m/M$. Molecular weight (if it has no dimensions) is the same as the molar mass number [7].

After the expert was able to weigh the gas carefully, research was carried out on gases and gas reactions, and finally the laws regarding gas reactions were obtained, one of which was Avogadro's law, which states:

Equal volumes of two gases at the same temperature and pressure. Two volumes of hydrogen contain twice the number of molecules as in one volume of oxygen, according to the chemical equation for the reaction.

Avogadro's hypothesis states that gases of the same volume have the same number of particles when they are at the same temperature and pressure. One aspect of the hypothesis called Avogadro's law is that it states that the volume and amount (in moles) of a gas are directly related when pressure and temperature are constant [4].

Volatile compounds are organic compounds that have a molecular weight range of 50-200 Daltons; with a low molecular weight, these compounds can evaporate easily and diffuse in the gas phase and in biological systems. If these compounds evaporate, the quality of the aroma and taste of the components will be affected and decreased. The molecular weight of volatile compounds can be measured based on measuring the density of the vaporized gas.

A gas will always be influenced by changes in environmental pressure and temperature. Various gas laws state that there is a dependence of a certain amount of gas on pressure, temperature, and volume. These gas laws can be obtained from experimental observations. Based on this, the molecular weight of volatile compounds can be determined. determined using the ideal gas equation, which is based on measuring the density of the gas [5].



2. Materials and Method

Tools and materials

In this practicum, several tools were used, namely an Erlenmeyer flask (150 ml), a beaker (600 ml), aluminum foil, a rubber band, a needle, an analytical balance, a desiccator, and a barometer. As for the materials used in this practicum, namely volatile liquids (CHCl_3 and CCl_4).

Making process

Take a clean, dry, small-necked Erlenmeyer flask and weigh it. Cover the flask with aluminum foil using a rubber band. Weigh the flask with the foil and rubber band. Put 5 mL of volatile liquid into the flask. Close it tightly with a rubber band. Make a small hole in the aluminum foil with a needle so that steam can escape. Immerse the flask in a water bath with a temperature of approximately 100°C . Leave the flask in the water bath until all the liquid has evaporated. Record the temperature of the water bath. Once all the liquid has evaporated, remove the flask from the bath. Dry the outside of the flask with a cloth. Place the flask in a desiccator and weigh it again once all the steam has returned to liquid. Determine the volume of the flask by filling it with water until it is full and measuring its mass. The formula for the volume of water contained in the flask is $q = m/V$. Measure the atmospheric pressure with a barometer. Then, determine the values of q and M_r .

3. Result

Eksperiment Result

Table 1. Table Eksperiment Result

Treatment	Result
Erlenmeyer mass + aluminum foil + rubber band	71,9934 g
Water bath temperature	90°C
Erlenmeyer mass + aluminum foil + rubber band + steam liquid	72,6130 g
Mass of Water + erlenmeyer	167,7884 g
Erlenmeyer volume	100 ml
Air pressure	1 atm
Mass of empty Erlenmeyer	71,4504 g



4. Discussion

The objective of this practicum is to determine the relative mass of the molecules of the volatile compounds that serve a purpose. The relative molecular mass of a compound can easily be determined by measuring the density of its vapor.

Molecules consist of interconnected arrangements of atoms that are bound in a fixed structure. Molecular mass is the total value of the atomic masses of the atoms that make up a molecule. These atoms are arranged into a formula molecule. Relative molecular mass, denoted by M_r , is defined by the International Union of Pure and Applied Chemistry (IUPAC) as "the mass ratio of a substance molecule to 1/12 the mass of a C-12 atom; the unit is the atomic mass unit." [7]

In this experiment, the sample used was chloroform (CHCl_3). The molecular mass of chloroform was determined based on density measurements through evaporation and condensation, as well as by calculating the difference in mass of the chloroform before and after evaporation. CHCl_3 is a volatile compound.

Volatile compounds have a boiling point lower than water's boiling point; examples include CHCl_3 and CCl_4 . The relative molecular mass (M_r) of a volatile compound is determined by measuring the density of the gas. Therefore, the compound must first be heated until it becomes a gas. [3]

During the experiment, an empty Erlenmeyer flask was weighed, yielding a mass of 71.4504 g. Then, the flask was weighed again. Blanks, along with aluminum foil and rubber bands, were obtained with a mass of 71.9934 g, and then CHCl_3 was added. Place 5 mL into an Erlenmeyer flask, then cover it with aluminum foil tied with a rubber band.

Aluminum foil is filled with small holes for the purpose of the steam outlet exits. Then the Erlenmeyer is soaked in a water bath until all volatile liquid has evaporated. When the liquid evaporates to a water bath temperature of 90°C , the reason for measuring the temperature of the bath is because of the temperature. It is the environment that influences the pressure of volatile compound gases. The gas pressure of volatile compounds is directly proportional to ambient temperature. The higher the environmental temperature, the higher the pressure of volatile compound gases. An equation of state, or ideal gas, is a thermodynamic equation that describes the state of matter under a set of conditions in physics. The ideal gas equation is a constitutive equation that provides a mathematical relationship between two or more state functions related to matter, such as temperature, pressure, volume, and internal energy. [8] The ideal gas equation states that:

$$PV = nRT$$



According to the ideal gas equation, gas pressure is directly proportional to temperature. This means that as the temperature of the environment increases, so does the pressure of the volatile compounds.

In experiments to determine the relative molecular mass of volatile compounds, the ambient temperature is measured with a thermometer. Then, the ambient temperature is used to calculate the gas pressure of the volatile compounds using the ideal gas equation.

However, if the temperature of the system is measured, the pressure of the compound gas and the volatiles obtained will vary with the gas pressure and the actual volatile compounds. This is because the system temperature is not always the same as the ambient temperature. The system temperature can be influenced by several factors, such as

Heat from the heater: The heater evaporates volatile compounds and produces heat. This heat can affect the system's temperature. The heat of volatile compounds: Volatile compounds that evaporate also produce heat. This heat can also affect the system temperature.

Therefore, to obtain accurate results, the temperature of the environment in which the measurement is taken must be used to calculate the gas pressure of the volatile compounds. Then, cooling was carried out. Afterward, the Erlenmeyer flask and water vapor were weighed, yielding a mass of 72.6130 g. Next, the Erlenmeyer flask was weighed with water, yielding a mass of 167.7884 g. The calculations yielded a mass of 0.6196 g of chloroform, a density of 3.692 g/L, and an atomic mass of 111.282 g/mol. Meanwhile, according to the Mr. of CHCl_3 , the theoretical value is 119.4 g/mol. The obtained percentage error of 6.79% is thought to be the result of this discrepancy. When the air in the Erlenmeyer flask is weighed, not all of the gas returns to liquid form when cooled. There is vapor that does not condense, and the weighing is not done carefully.

One way to determine the molecular weight (MW) of a compound is through calibration.

5. Conclusions

The practicum aimed to determine the relative molecular mass (Mr) of the volatile compound chloroform (CHCl_3) using density measurements through evaporation and condensation. Molecular mass is the sum of the atomic masses of the atoms in a molecule. IUPAC denotes Mr as the mass ratio of a substance's molecule to 1/12 the mass of a C-12 atom. Volatile compounds like CHCl_3 have lower boiling points than water. In the experiment, CHCl_3 was heated in an Erlenmeyer flask until it evaporated. Its mass was measured before and after evaporation. Ambient temperature was crucial because it affects



gas pressure via the ideal gas equation. However, the actual mass of the compound obtained (0.6196 g) resulted in an error of 6.79% compared to the theoretical Mr (119.4 g/mol). This error was attributed to factors such as incomplete condensation and inaccurate weighing. Common methods for determining molecular weight include Ragnault's method, Victor Meyer's method, and the limiting density method, which is particularly suitable for volatile compounds or real gases at low pressures.

References

1. N. Aini. (2017). Kimia Fisika 1, Malang: Universitas Negeri Malang.
2. S. Aprilyanti. (2020). Kimia Terapan, Purwodadi: CV.Sarnu Untung.
3. A. Amran. (2019). Penuntun Praktikum Kimia Fisika 1. Padang: Universitas Negeri Padang.
4. L. Sandra. (2022). Kimia Dasar. Padang: GET.
5. R. Marjoni. (2022). Modul Praktikum Fisika Farmasi. Solok: Mitra Cendikia Media.
6. Sukardo. (2016). Kimia Fisika. Jakarta: PT.Rineka Cipta.
7. B. Musa. (2023). Atom dan Senyawa kimia. Padang: GET.